(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 813 089 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
17.12.1997 Bulletin 1997/51

(51) Int Cl.6: G02B 26/08, G09F 9/37

(21) Application number: 97303985.2

(22) Date of filing: 09.06.1997

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: 10.06.1996 KR 9620611

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(54) Deformable mirror device and manufacturing method thereof

(57) A manufacturing method of a deformable mirror device includes the steps of forming an electrode layer (33a, 33b) on a substrate (30) in a predetermined pattern, forming a thick film (51) on the upper surfaces of the substrate (30) and the electrode layer (33a, 33b), forming a support plate (35) on the upper surface of the thick film (51), partially etching the thick film (51) to form at least one through hole (40), separating the support plate (35) into single portions, forming a post (39) on one side of the inner surface of the through hole (40), forming a reflecting plate (36) on the upper surface of the support plate (35), and removing the thick film (51).

FIG.7A

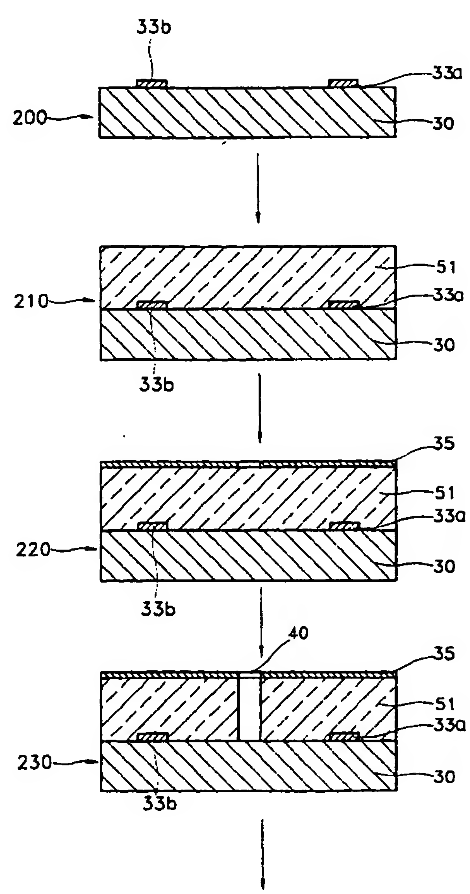

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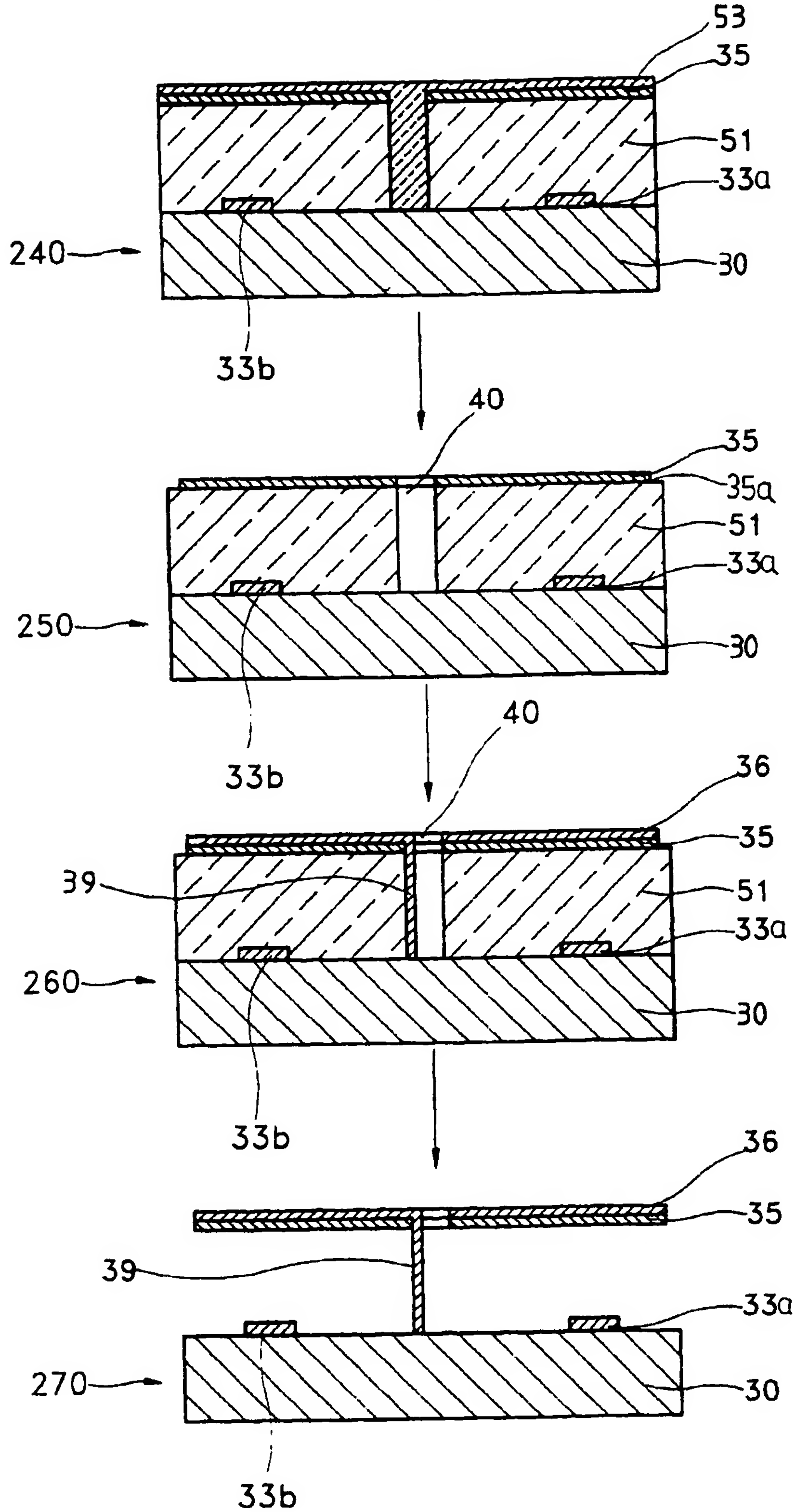
FIG.7B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33a
260
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36
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39
33a
270
30
33b

Description

The present invention relates to a deformable mirror device and a manufacturing method thereof, and more particularly, to a deformable mirror device having a large effective reflection area and a simple configuration and a manufacturing method thereof.

As shown in Figure 1, a typical deformable mirror device has a plurality of reflecting mirrors 1 each rotatably connected to a post 2 via a hinge 3. Each of the reflecting mirrors 1 is rotated by a static electricity, and reflects light incident thereinto at a predetermined angle. The deformable mirror device is used in a video displaying device for a projection television and in a light scanning device for a scanner, a copying machine, a facsimile machine, etc. The reflecting mirrors 1 of the deformable mirror device are arranged in a two-dimensional way having one mirror per pixel of an image. Each reflecting mirror 1 is rotated according to the respective pixel of an image signal to reflect light, whereby the color and brightness are controlled.

A manufacturing method of a 'multi-level deformable mirror device' disclosed in U.S. patent No. 5,083,857 by Texas Instrument Co. will be described with reference to Figure 2.

As shown in Figure 2, a static random access memory (SRAM) 12 and an oxide protective film 13 are sequentially formed on the upper surface of a substrate 11 including an address scanning circuit. Then, a first spacer layer 21 having a predetermined pattern 22 is formed on the oxide protective film 13, in step 100.

In step 110, a hinge 14 is formed on the upper surface of the first spacer layer 21 by a sputtering method, and an electrode 16 having a first support post 15 is formed on the upper surface of the hinge 14.

In step 120, a second spacer layer 23 is formed on the electrode 16, and a reflecting mirror 18 having a second support post 17 is then formed thereon. Here, the reflecting mirror 18 is typically formed by sputtering aluminium.

Finally, the first and second spacer layers 21 and 23 are removed, thereby completing a deformable mirror device, in step 130.

However, when defects are generated during manufacturing of the hinge 14, the reflecting mirror 18, etc. formed on the upper surface of the SRAM 12 during manufacture of the deformable mirror device, the SRAM 12 is damaged. Also, a plurality of layers must be sequentially formed on the upper surface of the substrate 11, so the manufacturing process of the deformable mirror device is complicated.

With a view to solve or reduce the above problems, it is an aim of embodiments of the present invention to provide a deformable mirror device having a large effective area for light reflection and a simple structure, and a simplified manufacturing method thereof.

According to a first aspect of the invention, there is provided a deformable mirror device comprising: a substrate; a plurality of electrodes formed on the upper surface of said substrate; a reflecting mirror installed over said electrodes to be able to incline with respect to said electrodes; and at least one post of which one end is connected to said substrate between said electrodes and the other end is integrally combined with said reflecting mirror to support said reflecting mirror, and having elasticity so that said reflecting mirror can be inclined.

Preferably, said reflecting mirror is formed of aluminium.

Preferably, a through hole is formed through said reflecting mirror at the portion where said other end of said post is combined with said reflecting mirror.

Said through hole may be formed in the shape of one of a rectangle, a triangle, a trapezoid, or a combination of the rectangle with a trapezoid.

Said reflecting mirror may comprise: a support plate with a through hole, supported by said post and inclined by static electricity which is generated between said support plate and said electrodes; and a reflecting plate formed on the entire upper surface of said support plate so that said through hole can be covered, for reflecting incident light.

According to a second aspect of the invention, tehre is provided a method of manufacturing a deformable mirror device, comprising the steps of: forming an electrode layer on a substrate in a predetermined pattern; forming a thick film on the upper surfaces of said substrate and said electrode layer; forming a support plate having a predetermined pattern on the upper surface of said thick film; situating a mask having a predetermined pattern on the upper surface of said support plate and partially etching said support plate and said thick film to form at least one through hole; coating a photoresist on the upper surface of said support plate and within said through hole and exposing and etching said coated photoresist using a mask having a predetermined pattern so that the edge portions of said support plate is removed, to divide said support plate into separate portions; forming a post on one side of the inner surface of said through hole by a sputtering; forming a reflecting plate on the upper surface of said support plate; and removing said thick film.

According to a third aspect of the invention, there is provided a method of manufacturing a deformable mirror device, comprising the steps of: forming an electrode layer on a substrate in a predetermined pattern; forming a thick film on the upper surfaces of said substrate and said electrode layer; situating a mask having a predetermined pattern on the upper surface of said thick film and partially etching said thick film to form at least one through hole; forming a support plate on the upper surface of said thick film and forming a post on one side of the inner surface of said through hole by sputtering; coating a photoresist within said through hole and exposing and etching said coated photoresist using a mask having a predetermined pattern so that the edge

portions of said support plate are removed, to separate said support plate into single portions; forming a photoresist layer within said through hole; forming a reflecting plate on said support plate and said photoresist layer to fill up the upper part of said through hole; and removing said thick film and said photoresist layer.

Preferably, at least one of said support plate, said reflecting plate and said post is formed of aluminium.

Said through hole may be formed in the shape of one of a rectangle, a triangle, a trapezoid, a letter T, or a combination of a rectangle with a trapezoid.

Said thick film is preferably formed of at least one selected from the group consisting of photoresist, polymethyl methacrylate (PMMA) or polyimide.

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 1 is a plan view of a conventional deformable mirror device;

Figure 2 shows a manufacturing process of the conventional deformable mirror device;

Figure 3 is a perspective view of a deformable mirror device according to an embodiment of the present invention;

Figures 4A through 4D are plan views showing various shapes of a through hole suitable for use in a mirror of the type of Figure 3;

Figure 5 is a perspective view of a deformable mirror device to explain another embodiment of a post of Figure 3;

Figure 6 is a sectional view of a deformable mirror device according to another embodiment of the present invention;

Figures 7A and 7B are sectional views showing a manufacturing method of a deformable mirror device according to an embodiment of the present invention; and

Figures 8A and 8B are sectional views showing a manufacturing method of a deformable mirror device according to another embodiment of the present invention.

Referring to Figure 3, a deformable mirror device according to an embodiment of the present invention includes a substrate 30 having an address scanning circuit (not shown) and at least a pair of electrodes 33a and 33b formed in a strip pattern on the upper surface of the substrate 30. A post 39 is formed between the electrodes 33a and 33b on the substrate 30. The post 39 is combined with the substrate 30 and vertical thereto, and can be bent elastically.

A reflecting mirror 37 is combined with the upper end of the post 39. The reflecting mirror 37 is a two-layered structure comprised of a support plate 35 and a reflecting plate 36 formed on the support plate 35. The support plate 35 faces the electrodes 33a and 33b, and the angle of the reflecting mirror 37 is varied by static electricity between the support plate 37 and the electrodes 33a and 33b. Also, the reflecting plate 36 reflects incident light.

A through hole 40 for forming the post 39 therethrough is formed in the reflecting mirror 37. The reflecting plate 36 and the post 39 are formed as one body by the sputtering or the evaporation method through the through hole 40. At this time, it is preferable that the post 39 is formed thinly, by the sputtering or evaporation method in the direction indicated by an arrow A, to facilitate the inclination of the reflecting mirror 37. Also, it is preferable that the area of the through hole 40 is reduced to enlarge the effective reflection area of the reflecting mirror 37 as much as possible.

The through hole 40 can have a shape of not only a rectangle as shown in Figure 3 but also a triangle 42, a trapezoid 43, a letter "T" 44 and a combination 45 of the rectangle and the trapezoid, as shown in Figures 4A through 4D. Here, an arrow A in each drawing denotes the deposition direction.

As shown in Figure 5, the deformable mirror device according to the present invention can include two or more posts 39a and 39b formed in a line between the electrodes 33a and 33b on the substrate 30. When the number of the posts is not less than two, the reflecting mirror 37 can be prevented from being twisted by temperature and the residual stress.

Figure 6 shows a deformable mirror device according to another embodiment of the present invention. Here, reference numerals common to the previous drawings denote the same members as in the previous drawings. According to the present embodiment, a through hole is not present in a reflecting plate 36'. That is, the effective reflection area of the reflecting mirror 37 is enlarged by filling up the through hole 40 (see Figure 3) formed through the reflecting plate 36'.

In the operation of the deformable mirror device according to the present invention having such a structure, when electrical potential depending on the address scanning circuit of the substrate 30 of Figure 3 is applied through the electrodes 33a and 33b, static electricity is generated between the reflecting mirror 37 and the electrodes 33a and 33b due to a difference in electric potential, whereby a torque inclining the reflecting mirror 37 is generated. Accordingly, while the post 39 is bent, the reflecting mirror 37 is inclined at a predetermined angle. When there is no potential difference between the electrodes 33a and 33b and the reflecting mirror 37, the post 39 is restored to the original state and the reflecting mirror 37 goes back to a horizontal state.

Hereinafter, a manufacturing process of the deformable mirror device will be described with reference to Figures 7A and 7B. First, in step 200, electrodes 33a and 33b are formed in a predetermined shape on a substrate 30 made of silicon or glass. To be more specific, a metal to be used as a material of the electrodes 33a and 33b is coated onto the substrate 30 by the sputtering method or the evaporation method, and a photoresist (not shown) is then coated onto the resultant structure. Next, a mask corresponding to the pattern of the electrodes 33a and 33b is situated on the photoresist, exposed and then etched. Such a process is carried out using a typical widely-known method.

In step 210, a thick film 51 composed of photoresist, polymethyl methacrylate (PMMA) or polyimide is formed in a thickness corresponding to the height of the post 39 (see Figure 3) on the substrate 30 on which the electrodes 33a and 33b are formed.

In step 220, a support plate 35 made of a metal such as aluminum (Al) having a predetermined pattern is formed on the upper surface of the thick film 51. The support plate 35 is formed by a lithography process.

In step 230, with a mask positioned over the support plate 35, the support plate 35 and the thick film 51 are partially etched by a reactive ion etching (RIE) method, thereby forming a through hole 40. As mentioned above, the through hole can be formed in various shapes, and more than one through hole can be formed.

In step 240, a photosensitive film such as a photoresist 53 is coated on the through hole 40 and the support plate 35 in order to separate the support plate 35 from adjacent support plates (not shown).

In step 250, a mask having a predetermined pattern is situated on the photoresist 53, exposed and then etched so that an edge portion 35a of the support plate 35 is removed, thereby separating the support plate 35 from adjacent support plates.

In step 260, the substrate 30, the thick film 51 and the support plate 35 are inclined at a predetermined angle and sputtering or evaporating is performed, thereby forming a post 39 on the inner surface of one side of the through hole 40. Simultaneously, a reflecting plate 36 is formed on the upper surface of the support plate 35. The post 39 and the reflecting plate 36 are formed of a metal having excellent electrical conductivity and reflectivity, e.g., aluminium (Al).

Lastly, the thick film 51 is removed by etching, in step 270.

Now, a manufacturing method of the deformable mirror device according to another embodiment described with reference to Figure 6 will be explained referring to Figures 8A and 8B.

First, the electrodes 33a and 35b are formed in a predetermined shape on the substrate 30 made of silicon or glass, in step 310. The thick film 51 is formed on the substrate 30 having the electrodes 33a and 33b formed thereon, in step 320.

Then, a mask is situated on the thick film 51 and partially etched by the reactive ion etching (RIE) method, thereby forming a through hole 40', in step 330. As described above, the through hole can be formed in various shapes, and more than one through hole can be formed.

In step 340, the substrate 30 and the thick film 51 is inclined at a predetermined angle and sputtering or evaporating is performed, thereby forming the post 39 on the inner surface of one side of the through hole 40'. Simultaneously, the support plate 35 is formed on the upper surface of the thick film 51. The post 39 and the support plate 35 are formed of a metal having a superior electrical conductivity, e.g., aluminum (Al). Thereafter, the edge portion 35a of the support plate 35 is removed so that the support plate 35 is separated from adjacent support plates, which step is not shown.

Next, a photoresist layer 55' is formed within the through hole 40' through which the post 39 is formed, in step 350. A reflecting plate 36' is formed on the resultant structure, in step 360. At this time, the reflecting plate 36' is formed to be able to fill up the through hole 40'. Then, the thick film 51 and the photoresist layer 55' are removed, thereby completing the deformable mirror device, in step 370.

Examples of deformable mirror devices according to the present invention have a simple structure, and as demonstrated in the Figure 6 embodiment and Figure 8 method the through hole formed in the reflecting plate may be filled, so that the effective reflecting area of the reflecting plate can be further enlarged.

The manufacturing process of deformable mirror devices according to the present invention has only a small number of manufacturing steps and is simple, so that the scope for production efficiency can be increased.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying

claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A deformable mirror device comprising:

   a substrate (30);

   a plurality of electrodes (33a, 33b) formed on the upper surface of said substrate (30);

   a reflecting mirror (35, 36) installed over said electrodes (33a, 33b) to be able to incline with respect to said electrodes (33a, 33b); and

   at least one post (39) of which one end is connected to said substrate (30) between said electrodes (33a, 33b) and the other end is integrally combined with said reflecting mirror (35, 36) to support said reflecting mirror (35, 36), and having elasticity so that said reflecting mirror (35, 36) can be inclined.

2. A deformable mirror device as claimed in claim 1, wherein said reflecting mirror (36) is formed of aluminium.

3. A deformable mirror device as claimed in claim 1 or 2, wherein a through hole (40, 42, 43, 44, 45) is formed through said reflecting mirror (35, 36) at the portion where said other end of said post (39) is combined with said reflecting mirror (35, 36).

4. A deformable mirror device as claimed in claim 3, wherein said through hole (40, 42, 43, 44, 45) is formed in the shape of one of a rectangle, a triangle, a trapezoid, or a combination of the rectangle with a trapezoid.

5. A deformable mirror device as claimed in any of claims 1 to 4, wherein said reflecting mirror (35, 36) comprises:

   a support plate (35) with a through hole (40, 42, 43, 44, 45), supported by said post (39) and inclined by static electricity which is generated between said support plate (39) and said electrodes (33a, 33b); and

   a reflecting plate (36') formed on the entire upper surface of said support plate so that said through hole can be covered, for reflecting incident light.

6. A method of manufacturing a deformable mirror device, comprising the steps of:

   (200) forming an electrode layer (33a, 33b) on a substrate (30) in a predetermined pattern;

   (210) forming a thick film (51) on the upper surfaces of said substrate (30) and said electrode layer (33a, 33b);

   (220) forming a support plate (35) having a predetermined pattern on the upper surface of said thick film (51);

   (230) situating a mask having a predetermined pattern on the upper surface of said support plate (35) and partially etching said support plate (35) and said thick film (51) to form at least one through hole (40, 42, 43, 44, 45);

   coating a photoresist (53) on the upper surface of said (240, 250) support plate (35) and within said through hole (40, 42-45) and exposing and etching said coated photoresist (53) using a mask having a predetermined pattern so that the edge portions (35a) of said support plate (35) are removed, to divide said support plate (35) into separate portions;

   (260) forming a post (39) on one side of the inner surface of said through hole (40, 42-45) by a sputtering;

   (260) forming a reflecting plate (36) on the upper surface of said support plate (35); and

   (270) removing said thick film (51).

7. A method of manufacturing a deformable mirror device, comprising the steps of:

   (310) forming an electrode layer (33a, 33b) on a substrate (30) in a predetermined pattern;

   (320) forming a thick film (51) on the upper surfaces of said substrate (30) and said electrode layer (33a, 33b);

   (330) situating a mask having a predetermined pattern on the upper surface of said thick film (51) and partially etching said thick film (51) to form at least one through hole (40');

   (340) forming a support plate (35) on the upper surface of said thick film and forming a post (39) on one side of the inner surface of said through hole (40') by sputtering;

   (350) coating a photoresist (55) within said

through hole (40') and exposing and etching said coated photoresist using a mask having a predetermined pattern so that the edge portions (35a) of said support plate (35) are removed, to separate said support plate (35) into single portions;

(360) forming a reflecting plate (36') on said support plate and said photoresist layer (55') to fill up the upper part of said through hole (40'); and

(370) removing said thick film (51) and said photoresist layer (55').

8. A method of manufacturing a deformable mirror device as claimed in claim 6 or 7, wherein at least one of said support plate (35), said reflecting plate (36, 36') and said post (39) is formed of aluminium.

9. A method of manufacturing a deformable mirror device as claimed in claim 6, 7 or 8, wherein said through hole (40, 42-45) is formed in the shape of one of a rectangle, a triangle, a trapezoid, a letter T, or a combination of a rectangle with a trapezoid.

10. A method of manufacturing a deformable mirror device as claimed in claim 6, 7 or 8, wherein said thick film (51) is formed of at least one selected from the group consisting of photoresist, polymethyl methacrylate (PMMA) or polyimide.

FIG.1 (PRIOR ART)

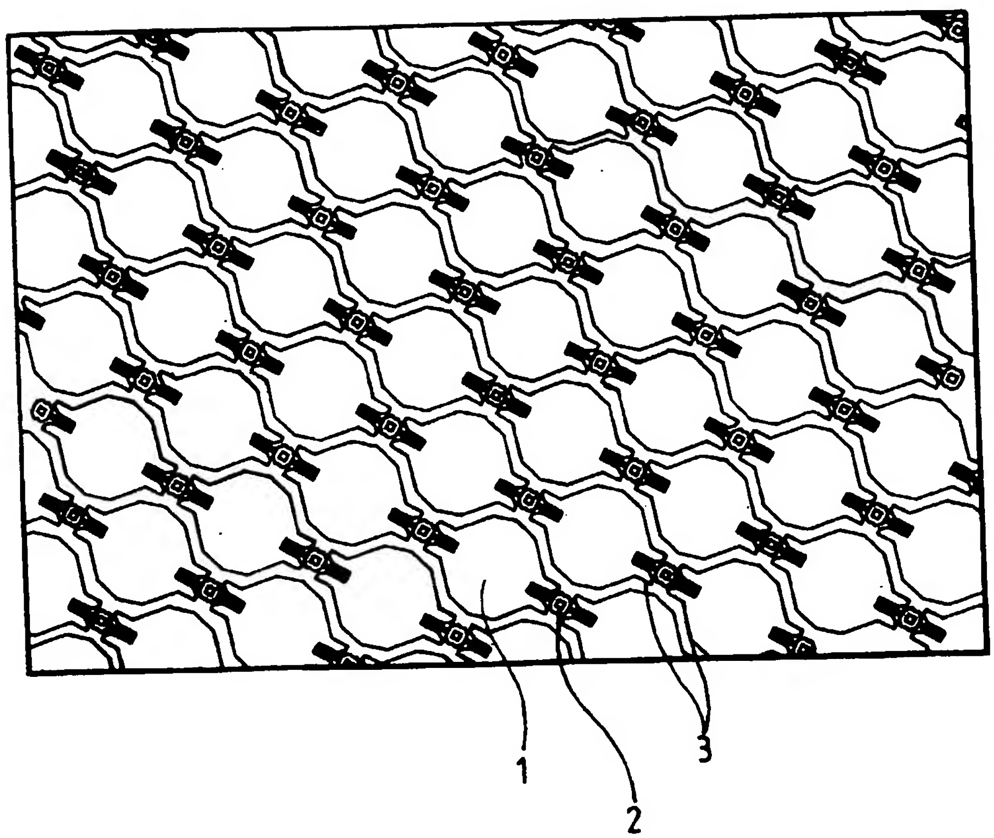

FIG.2 (PRIOR ART)

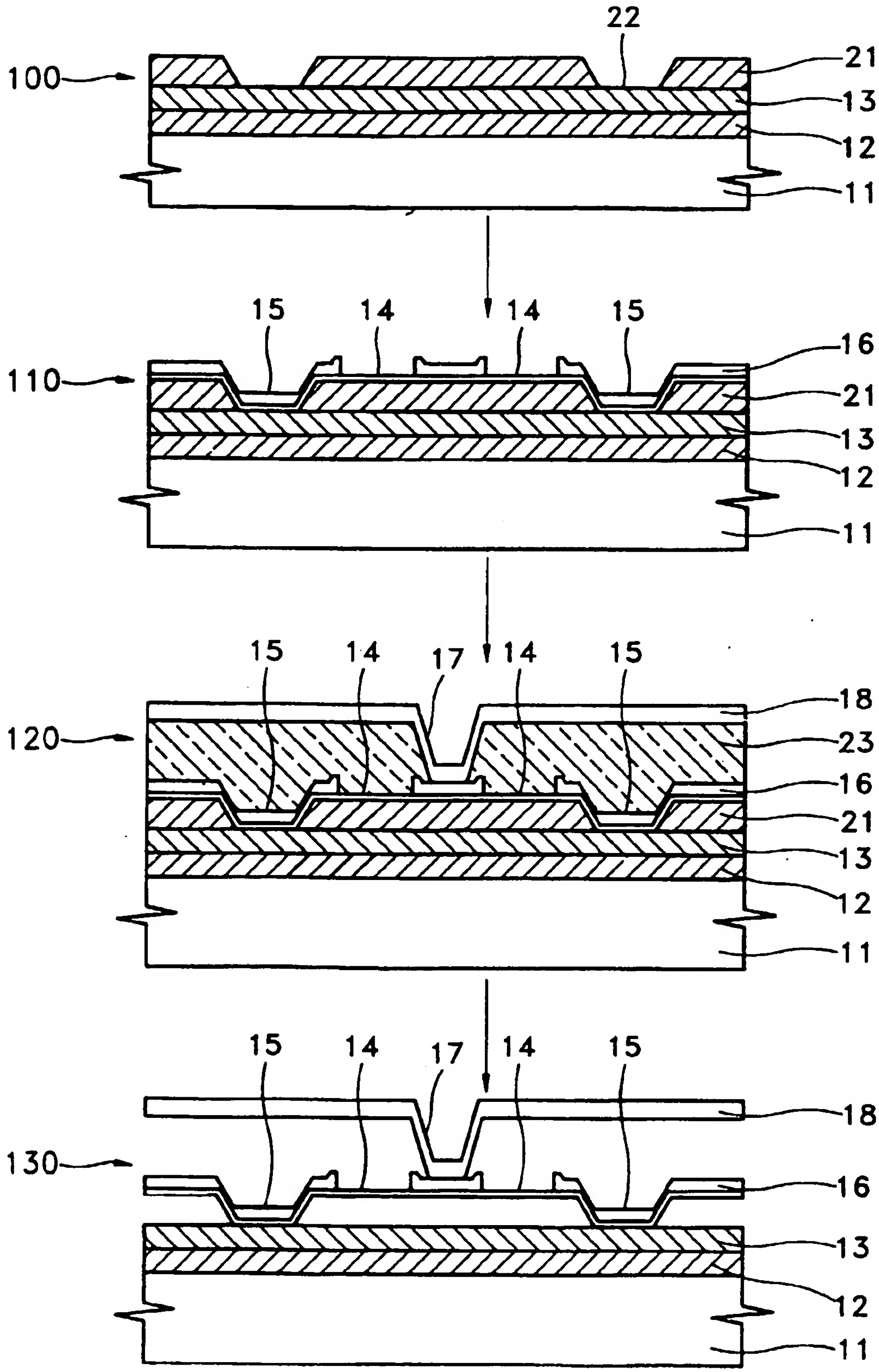

FIG.3

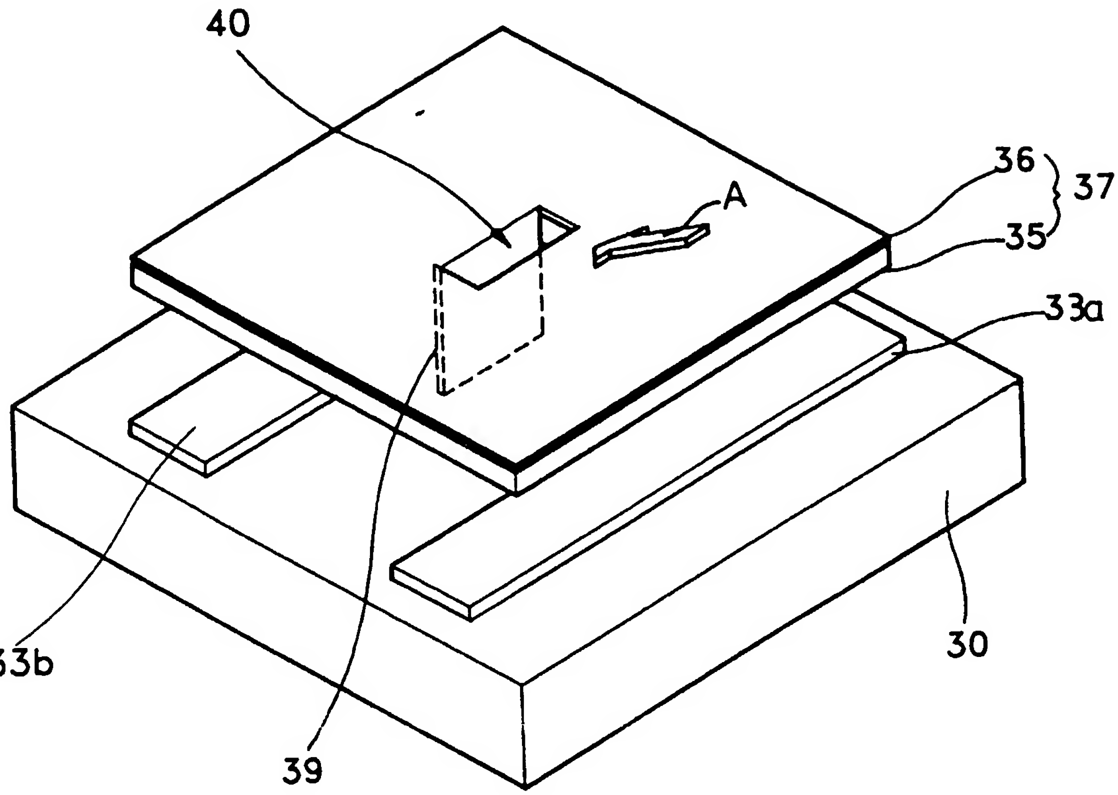

FIG.4A

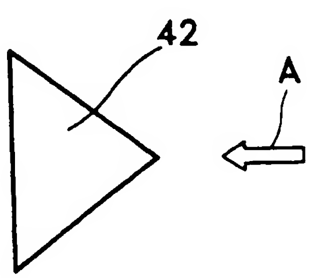

FIG.4B

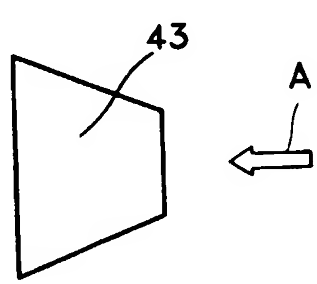

FIG.4C

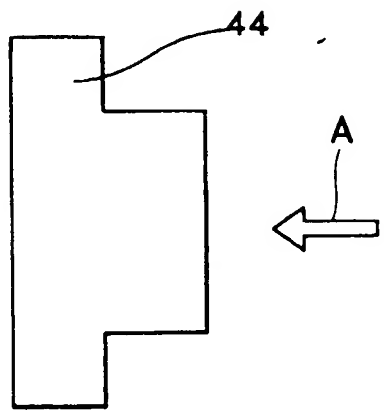

FIG.4D

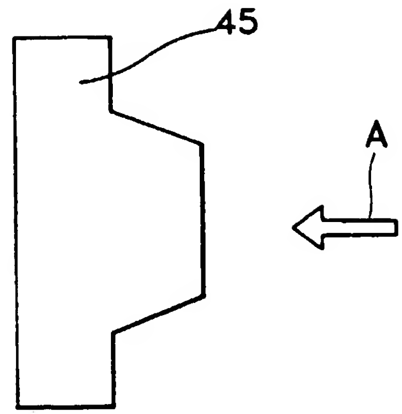

FIG.5

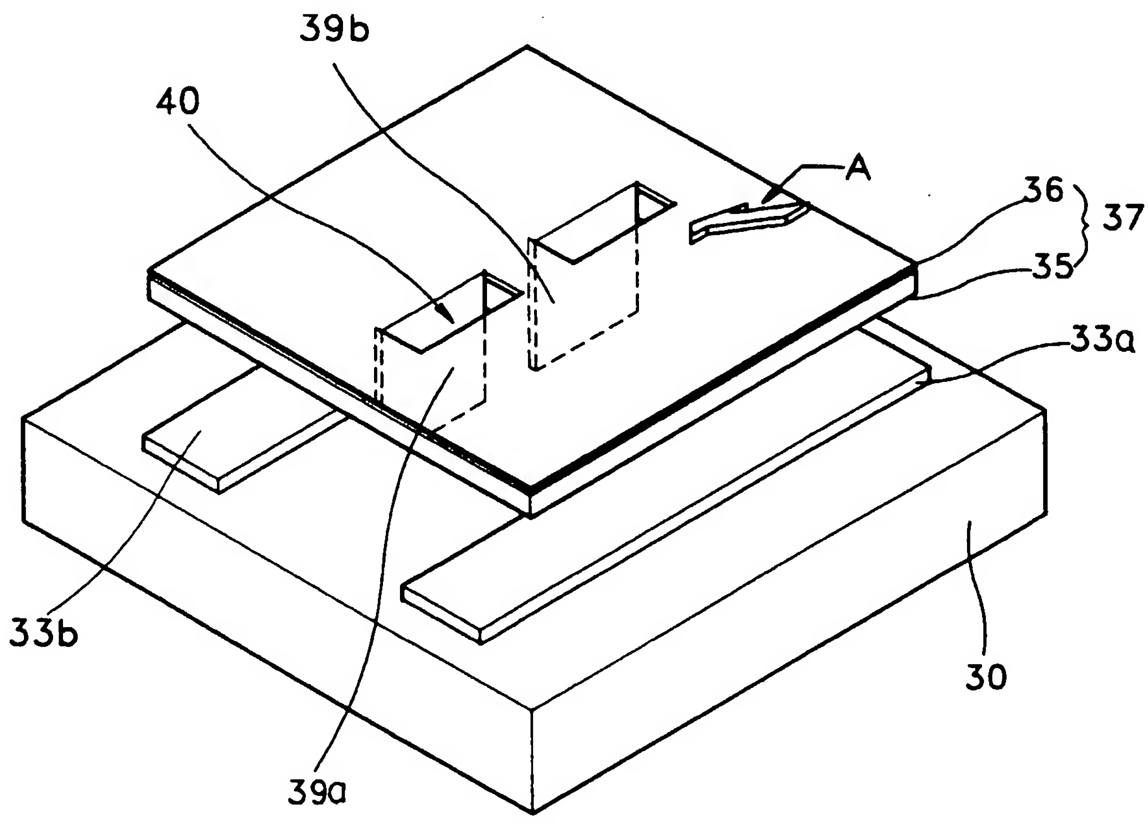

FIG.6

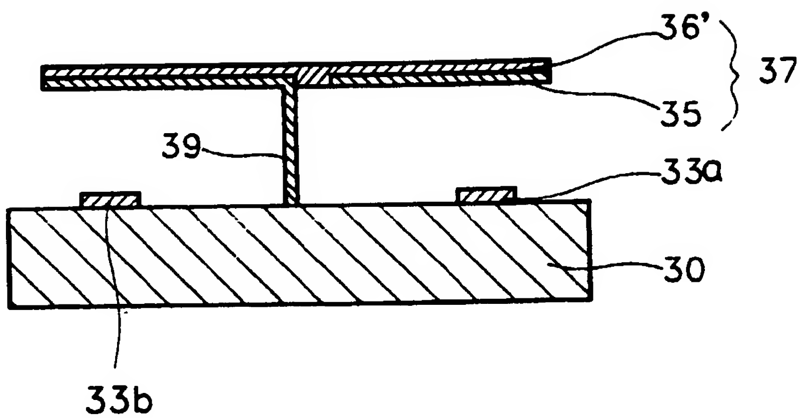

FIG.7A

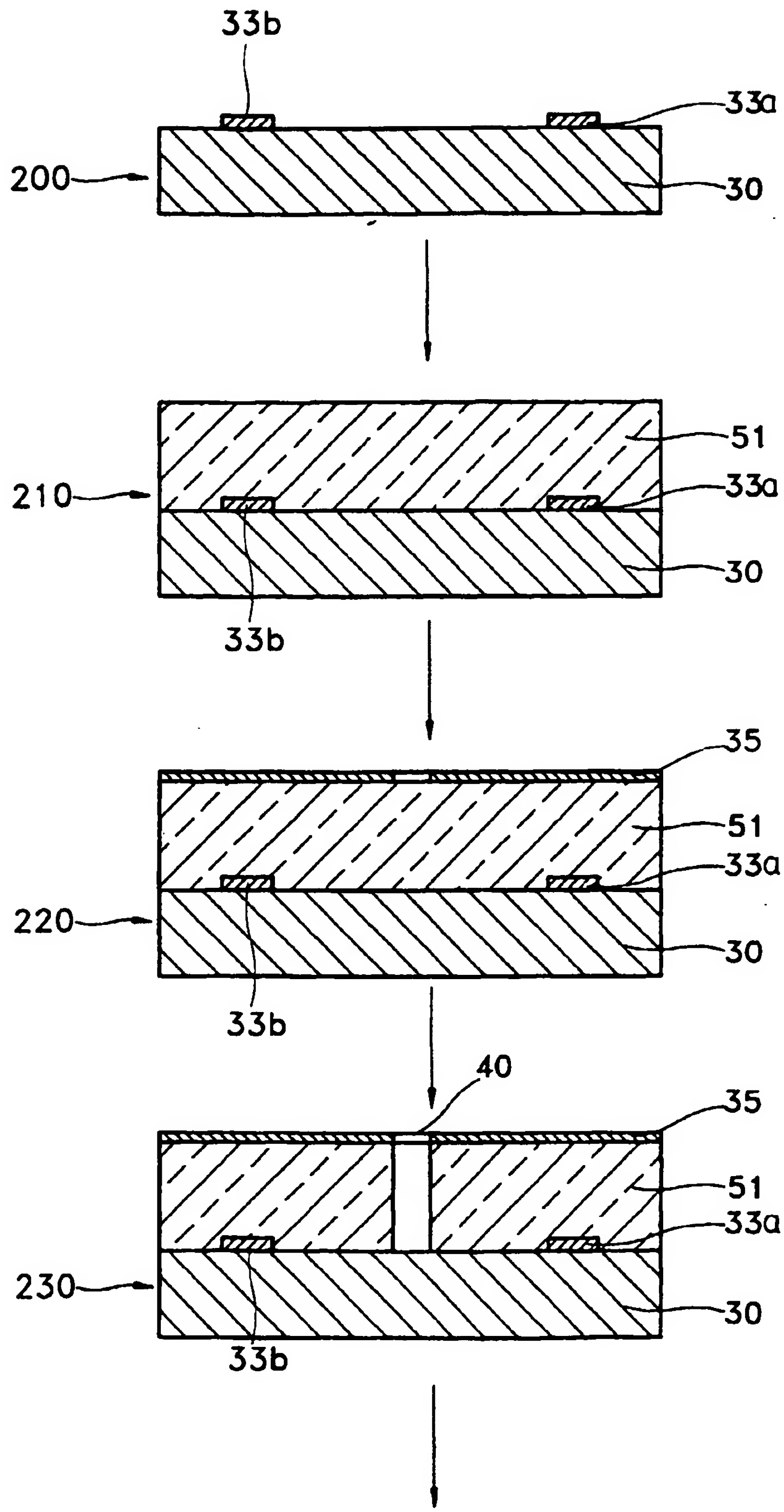
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FIG.7B

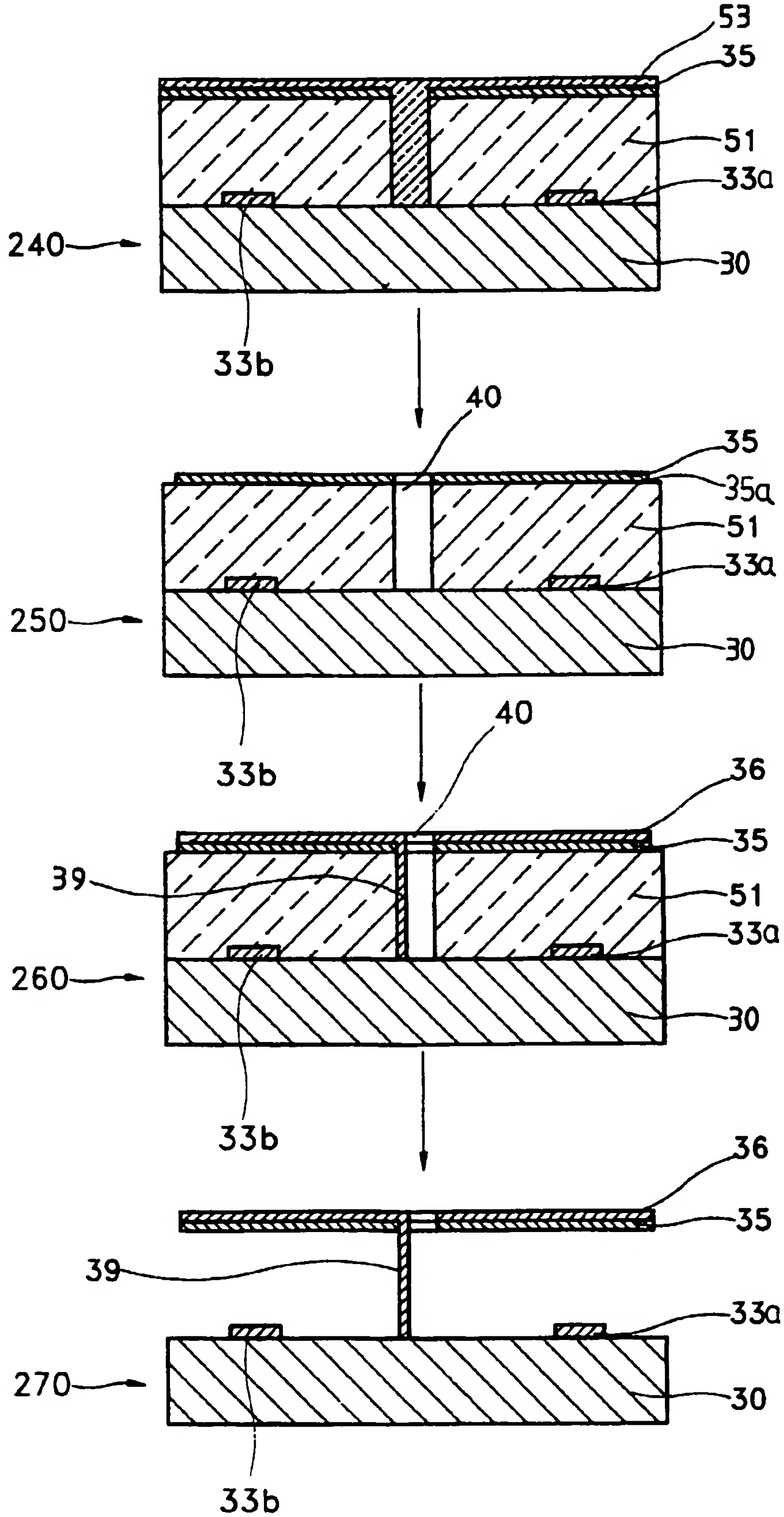
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FIG.8A

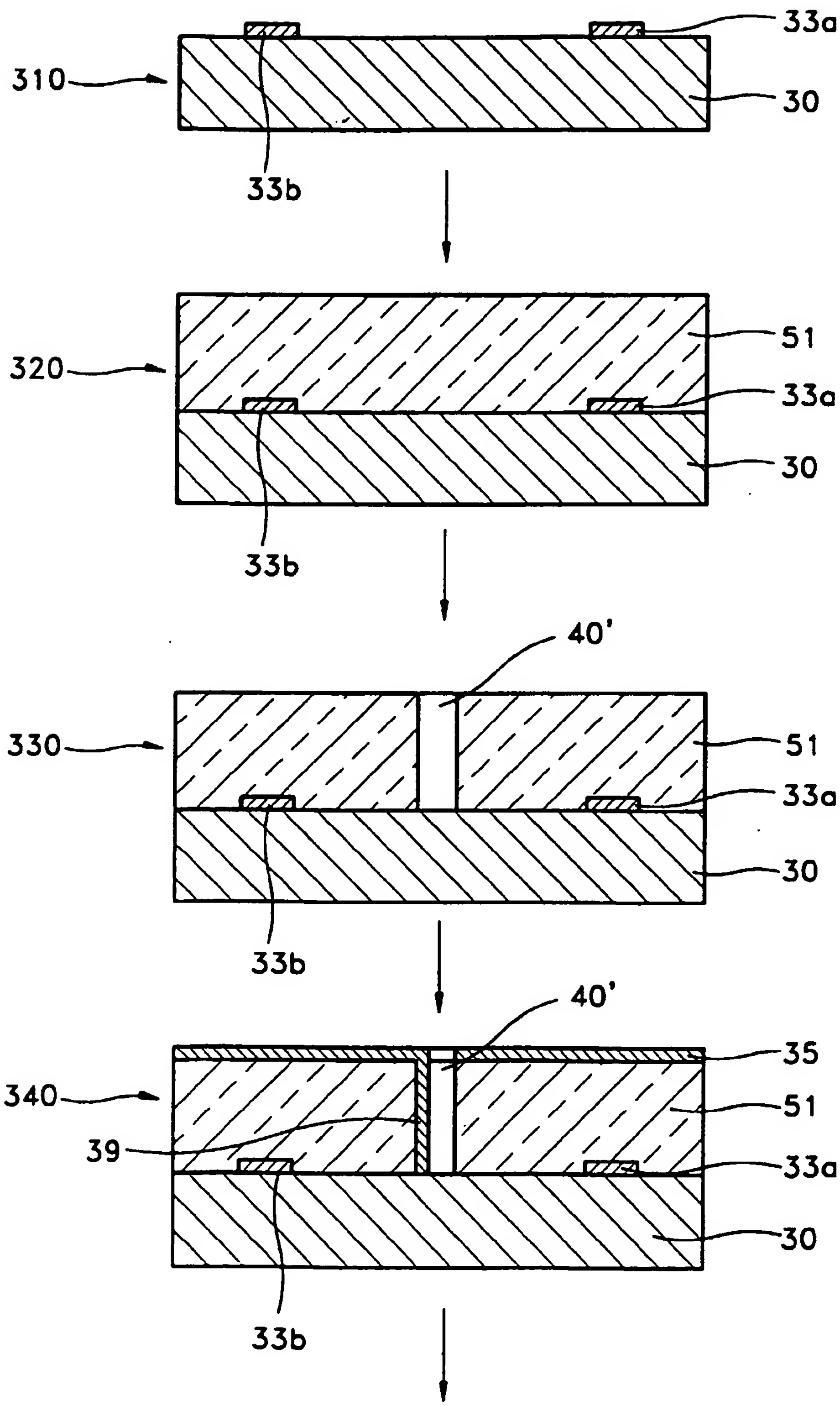
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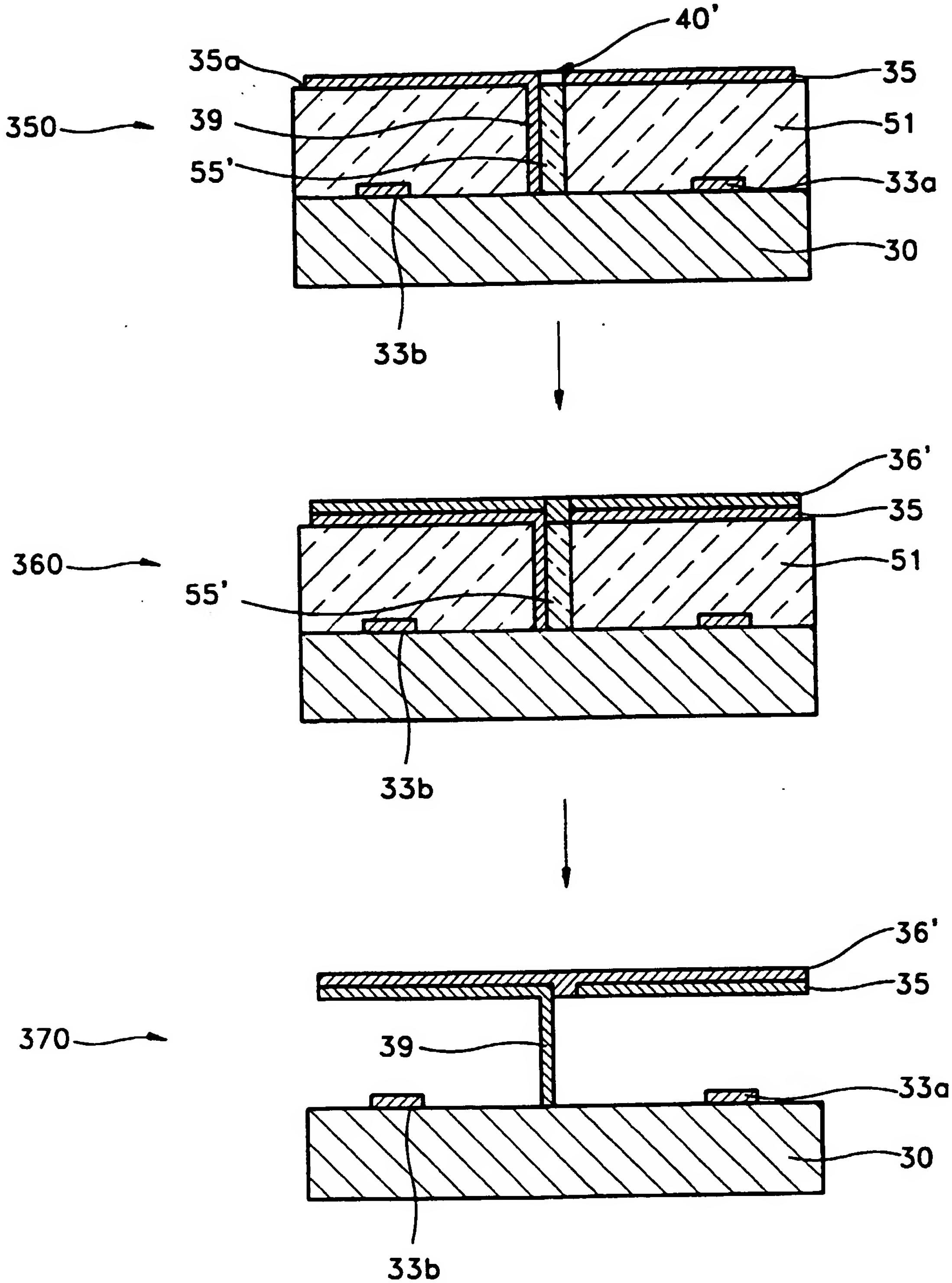
FIG.8B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